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Using LiDAR data to locate a Middle Woodland enclosure and associated mounds, Louisa County, Iowa

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ABSTRACT

LiDAR data is used to locate an enclosure reported at the McKinney site (13LA1) as well as destroyed mounds associated with the Toolesboro mound group National Historic Landmark (13LA29). Using various geo-visualization and interpolation techniques, one of us (Riley) located the earthwork enclosure, eight mounds, and possibly a ninth or an excavation spoil pile. An anomaly north of 13LA1 and within the detected enclosure area were also identified. There is no modern survey relating to these two anomalies. Our results support historic accounts regarding the location and shape of the McKinney enclosure and its relationship to the Toolesboro mound group. All features found by LiDAR will be ground truthed in the future.

1. Introduction

This research focuses on two sites—the late prehistoric McKinney Oneota village site (13LA1) and the adjacent Toolesboro National Historic Landmark Mound Group (13LA29, Toolesboro mound group) located on the uplands and the adjacent bluff edge respectively overlooking the confluence of the Iowa and Mississippi rivers in Louisa County, Iowa (Fig. 1). The main occupation of the McKinney site dates from A.D. 1500–1650 (Hollinger, 2005:90–91; Tiffany, 1988:298–299). The Toolesboro mound group is a component of the Havana tradition of the Middle Woodland period (200 B.C.–A.D. 300) and was part of an exchange network in exotic and raw materials and ideology in Eastern North America archaeologists originally termed the Hopewell Interaction Sphere (Struever, 1964). Geometric earthworks are important elements of the Middle Woodland period cultural landscape in the Eastern Woodlands. They are a central component of Hopewell centers in Ohio, but less so in the Havana tradition of the central Illinois Valley.

A small portion of the McKinney Oneota village occupation extends into the area of a geometric earthwork (the "Old Fort") first reported in 1841 by John B. Newhall (1841:231–233; Fig. 2), but no surface expression of this historically reported enclosure has been detected since the 19th century. Archaeologists believe this earthwork is associated with the earlier adjacent Toolesboro mound group (Tiffany, 1988; Whittaker and Green, 2010). McKinney thus has two cultural components of disparate age, and some researchers have likely mistakenly associated the enclosure with the much later Oneota village because of surface recovery of Oneota artifacts in the enclosure vicinity. Several earthwork enclosures are reported along the Iowa side of the Mississippi in northeast and southeast Iowa (Whittaker and Green, 2010; Wedel, 1959:12–15). The McKinney enclosure is one of only three enclosures associated with mortuary mound features of Middle Woodland age among the five Early and Middle Woodland earthwork features reported by Whittaker and Green (2010:29–30), and it is the only one associated with a mortuary complex of recognized national significance. Thus, locating and documenting the enclosure and other associated features is of major importance for the archaeological record. This article reports on the location of the earlier Middle Woodland enclosure at the McKinney site and its relation to the Toolesboro mound group using Light Detection and Ranging (LiDAR) data.

Any Middle Woodland habitation site associated with the Toolesboro mound group and enclosure has yet to be identified. If it exists and is like typical Havana tradition settlements in the Illinois Valley and Middle Woodland settlements locally, the village site at Toolesboro would be at the bluff base on a terrace in the

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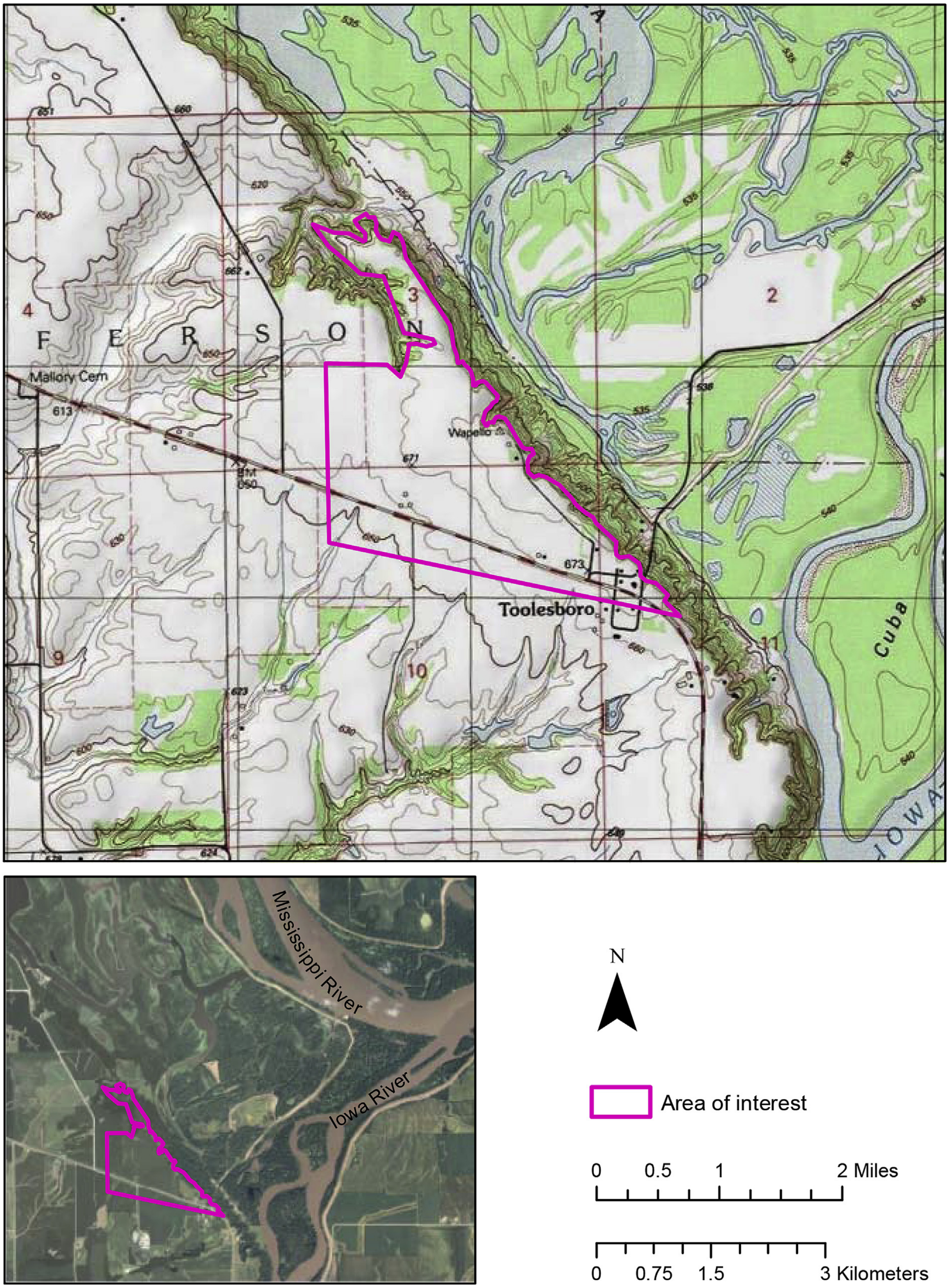

Fig. 1. Project area base map for LiDAR analysis. From USGS Toolesboro quadrangle, 7.5 series, 1953, photorevised, 1976. Air photo from ArcGIS Online World Imagery dataset, accessed April 2012.

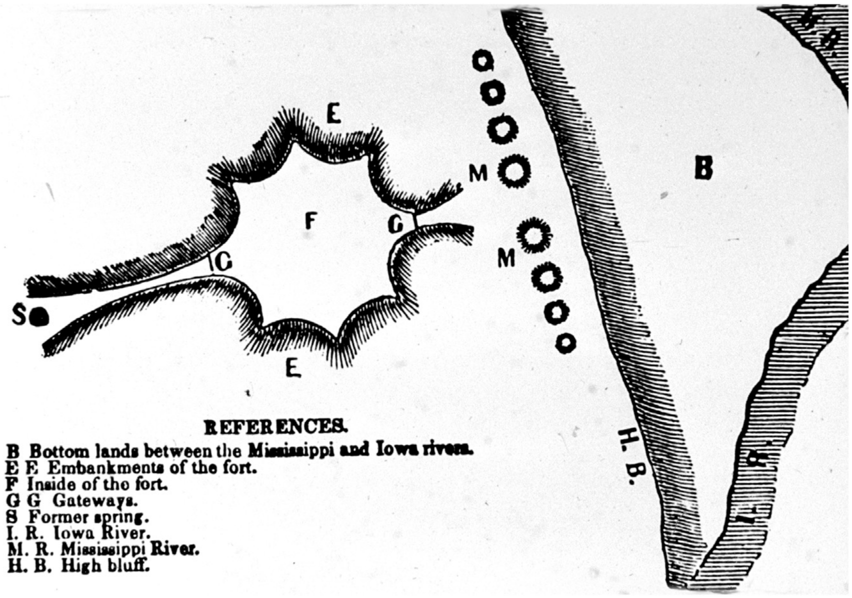

Fig. 2. Newhall's (1841:234) depiction of the McKinney site enclosure and the Toolesboro mound group.

Mississippi–Iowa river bottomlands below the mounds (Fig. 1; Green, 1993:2). Today, this area is difficult to survey because of heavy timber and colluvial deposits, and the site, in any event, may have been destroyed by erosion associated with fluctuating water levels on the Iowa–Mississippi river system resulting from the lock and dam system on the Mississippi and the Coralville dam upstream on the Iowa River.

The McKinney site, the Toolesboro mound group, and the immediate surrounds have been the focus of archaeological study and speculation for over 170 years. An authoritative and thorough summary by Alex and Green (1995) documents the Toolesboro mound group and Middle Woodland archaeological research in this portion of the Mississippi Valley. The history of McKinney site studies and extensive archaeological investigations is reported by Tiffany (1988). More recent field research on the Oneota component at the McKinney site is reported by Hollinger (2005).

The earthen enclosure at McKinney was nearly obliterated at the time of Newhall's (1841) sketch (Fig. 2), and farming over ensuing 170 plus years has destroyed all visible surface expression of the enclosure. Various historic accounts give conflicting shapes (octagonal or circular) and dimensions for the McKinney enclosure (Alden, 1844; Hale, 1888; Newhall, 1841; Pratt, 1876:109; Shaw, 1878:258; Stevenson, 1879:98; Toole, 1868:52). Newhall's depiction is the best known, but perhaps the most embellished (Tiffany, 1988:233) since the octagonal form he depicts with curved rather than straight embankments between the point intersections would be unique for Middle Woodland enclosures in North America.

Archaeological work at the McKinney site in recent years has employed low oblique angle and orthogonal aerial photography, satellite imagery, and topographic mapping in an attempt to locate the enclosure (Tiffany, 1988). There is also a reported but unanalyzed geophysical survey conducted on the Oneota component of the McKinney site outside the area of interest (Hollinger, 2005). We now believe that these efforts repeatedly failed to locate the enclosure because researchers were looking in the wrong area for it. While it would seem easy to find the enclosure given its depiction by Newhall (Fig. 2), and its varied description by others (Alden, 1844; Hale, 1888; Newhall, 1841; Pratt, 1876:109; Shaw, 1878:258; Stevenson, 1879:98; Toole, 1868:52), none of these reports gave a precise location tied to obvious landmarks like the Toolesboro mound group or an established survey datum, making relocation efforts largely guesswork. These historical accounts led to the past suggested placement of the enclosure to the south and east of where we now believe it lies (Alex and Green, 1995:88; Tiffany, 1988:228).

The advent of Iowa's statewide LiDAR data collection provides a new approach to identify earthen archaeological features. One-meter shaded relief imagery created from LiDAR elevation data is available to the public through an internet viewer served by Iowa State University (http://ortho.gis.iastate.edu/), but the static data is far from sufficient to detect low-relief features. To locate earthen archaeological features that have been subject to historic excavations, or nearly two centuries of cultivation such as the McKinney enclosure, methods are required using specialized GIS software for surface interpolation and geovisualization of both the LiDAR-derived surfaces and the classified LiDAR point cloud.

The LiDAR elevation data in Iowa has already proven to be useful in the identification of burial mounds, semi-subterranean lodge features, trails and ridge fields, many of these features having only 20 cm relief or less (Riley, 2009, 2010). LiDAR datasets for two counties in Minnesota were effective in locating plowed-down burial mounds, and an earthwork enclosure in Scott County, MN even though the data were created under less-stringent specifications than Iowa's LiDAR data (Riley et al., 2010). A recent, digital survey of the Malchow mound group (13DM4) coupled with ground penetrating radar survey at the nearby Poisel mound sites (13DM226, 13DM338) southeast of Toolesboro near Kingston, Iowa, succeeded in clarifying internal site features and illustrating site complexity. In addition to the discovery of a new mound at 13DM338, two linear earthworks at the Malchow mound group were defined which may align with a newly discovered depression surrounding the largest of the Poisel site mounds (13DM226) (Whittaker, 2009a, 2009b).

With this information in mind Tiffany secured grant funding from the University of Wisconsin–La Crosse and contracted with Riley, then at The University of Iowa Office of the State Archaeologist (UI-OSA), to use Iowa LiDAR data to see if signatures could be located for the earthwork enclosure on the McKinney site and the associated burial mounds of the Toolesboro mound group.

2. Methods

Riley proceeded with the analysis without examination of the extant archaeological literature on the McKinney and Toolesboro sites so that her analysis was as unbiased as possible. All analyses were conducted using ESRI ArcGIS 10 Desktop software with the Spatial Analyst and 3D Analyst extensions. Some of the mass point data manipulation and analysis was conducted with QCoherent LP360 Basic software in the ArcGIS Desktop environment.

First, the Bare Earth Digital Elevation Model (BE DEM) block that included the study area (Fig. 1) was obtained from the Iowa Geological and Water Survey (IGWS). This dataset is a large raster consisting of cells, each representing 1 m^2 of area on the ground, attributed with elevation values to 1 cm precision. The BE DEM was further trimmed to the vicinity of the McKinney site and the Toolesboro mound group.

Next, a shaded relief image was created from the trimmed BE DEM to aid in identifying anomalies on the ground surface (Fig. 3). Brightness and contrast manipulation of the shaded relief image in ArcMap and Adobe Photoshop CS6 shown in Fig. 3 insert indicate a circular feature in the McKinney site as well as five conical mound features 13LA29– two of them were very faint, however. Further interpretation was needed by adding the BE DEM to an ArcScene environment, available with the ArcGIS 3D Analyst extension, where the vertical exaggeration of the elevation data was manipulated at an orthogonal view of the sites. Dynamic lighting effects not available in the ArcMap environment were used concurrently with changes in vertical exaggeration.

Fig. 3. Shaded relief image from ArcMap from the LiDAR data for sites 13LA1 and 13LA29. The conical burial mounds are clearly visible (delimited in yellow). A grayer shaded area in the northeast portion of the 13LA1 site area is the enclosure. The inset is a contrast-enhanced image of the enclosure. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

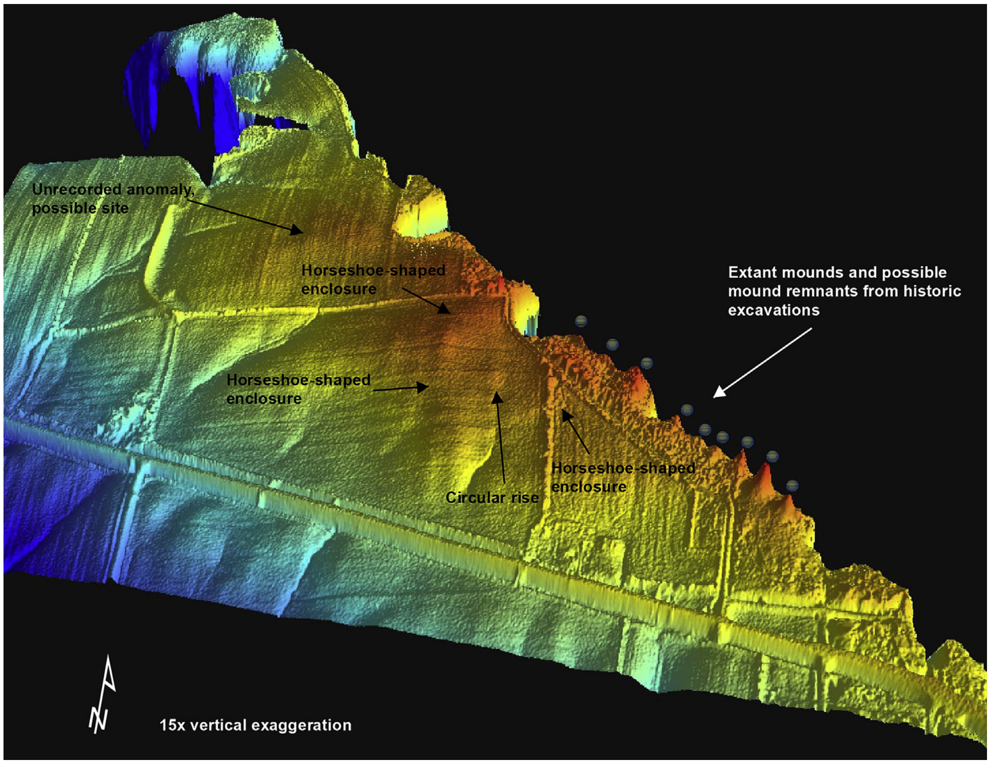

Fig. 4. Vertically- exaggerated BE DEM color- rendered by elevation, blue lowest, depicting the enclosure, the mound features and other previously unknown surface anomalies including a circular rise in the center of the enclosure. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

LiDAR data in its most basic form is a collection of points with each point having an assigned elevation value. The LiDAR data used had the points sorted into two categories, ground and non-ground, using automated software algorithms. These classified mass point datasets are available to the public in 2 × 2 km tiles for download from an internet map service hosted by University of Northern Iowa GeoTREE Center (http://www.geotree.uni.edu/lidar/). Tiles containing 13.1 million elevation data points were downloaded in order to see if the ground point density was sufficient enough to create a finer resolution BE DEM than the 1 m raster available and to also create a BE DEM by an alternative interpolation method from the one used for the statewide LiDAR project.

Inverse distance weighted (IDW) interpolation was used to create the 1 m BE DEMs available to the public and is the industry standard in producing large DEMs. However, IDW is not an exact interpolator, meaning that the resultant raster cell values (elevation) will not equal the input point's value at the same location. Each cell's value was calculated by averaging spatially weighted values of input points from a user-determined neighborhood. The resulting weighted values can vary both by the distance of the points from the calculated cell, and by what the user-defined influence distance has on the weight. An exact interpolator such as spline interpolation should lose less information on microtopography than IDW because the surface will be fitted to the actual values of the elevation points. Thus, the surface created by the BE DEM cells will intercept the elevations of the input points and only elevation values of raster cells in between points will be estimated.

3. Analysis and results

The IDW BE DEM at 10–15× vertical exaggeration clearly shows a horseshoe-shaped anomaly just northwest of the Toolesboro mound group with the ends facing the bluff edge (Fig. 4). The relief of the feature is no more than 5–10 cm higher than the surrounding ground surface and about 15 m wide. The maximum dimensions of the anomaly are approximately 160 × 200 m (525 × 56 ft); in the center is a circular rise up to 10 cm high and 38 m (125 ft) in diameter that may represent a hitherto unreported mound (Fig. 5). When traced from the outer edge, the enclosure feature

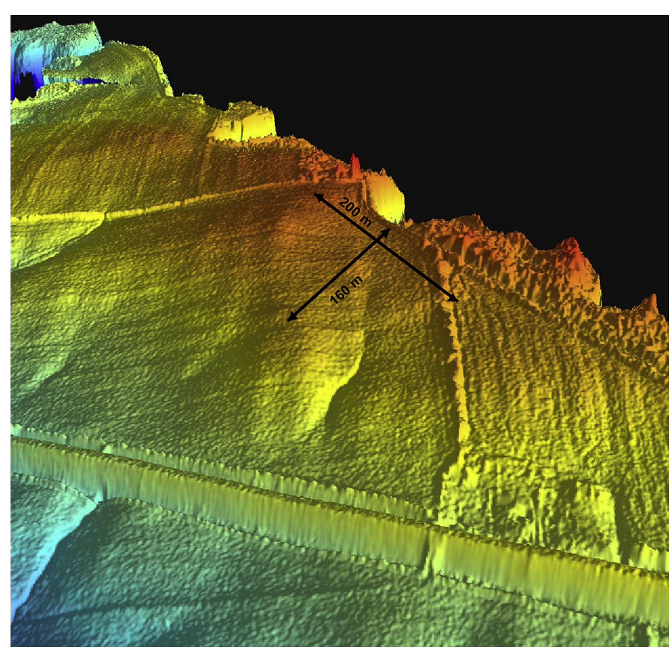

Fig. 5. Dimensions of the McKinney site enclosure feature.

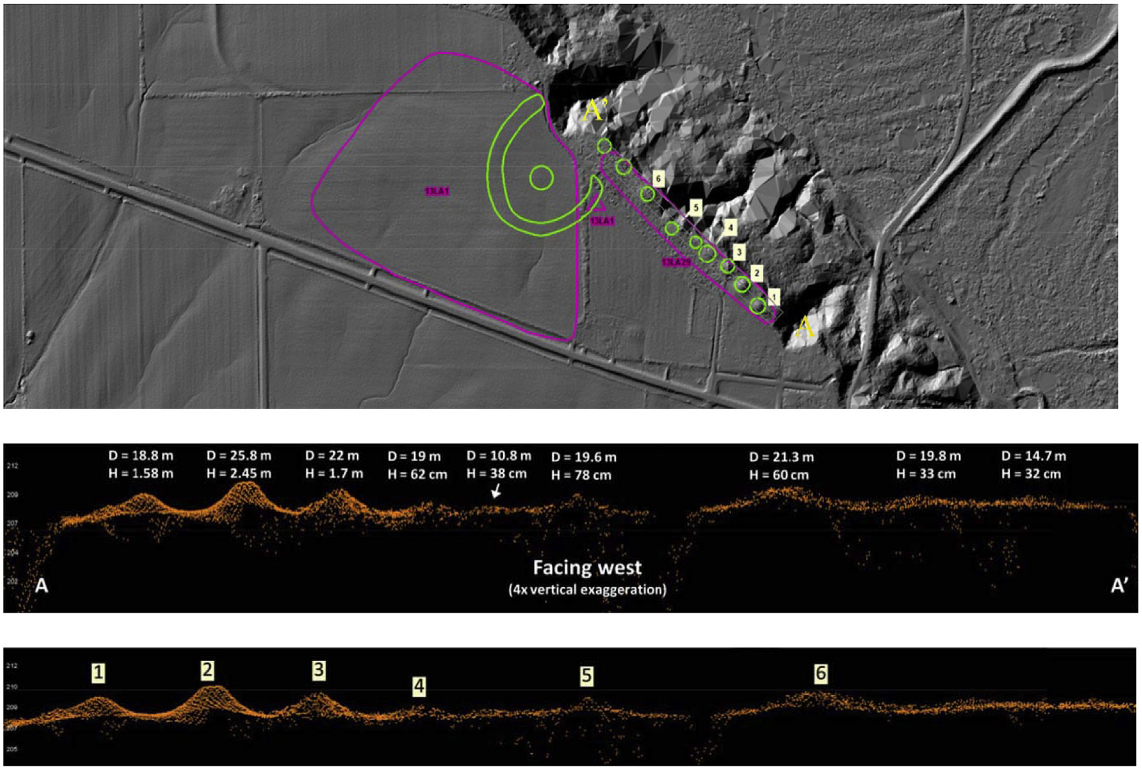

Fig. 6. Top: Shaded relief with detected features outlined in green. Bottom: Ground point profile of the Toolesboro mound group (13LA29) at 4× vertical exaggeration and with Orr's (1934) corresponding mound numbers. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

encompasses about 2.6 ha (6.4ac). The exaggerated surface also suggests vestiges of destroyed conical mounds along the bluff's edge in line with the mounds visible from the shaded relief image (Fig. 4). In Fig. 5 there are also two north-south parallel linear features immediately west of the enclosure feature that matches dimensions of excavations on the McKinney site (Hollinger, 2005; Tiffany, 1988).

The classified ground points from the three tiles were brought into ArcMap for further analysis of the McKinney and Toolesboro mound group sites. The point density over the areas covered in trees indicates that at the time the data was collected (May 5, 2010) the trees and understory vegetation were in bud-out or early leaf-out phase. The coverage is very patchy with an average point density along the bluff line over the Toolesboro mound group at 1 data point for every 2.9 m^2. Given the uneven nature of the point distribution and the sparse point density, creating a finer-resolution BE DEM for 13LA29 would not have been beneficial. Instead, a transect of the bluff line was taken with the ground points grouped in a 30 m–wide swath to visualize any subtle trends that may indicate a footprint of an excavated mound (Fig. 6). The profile at 4× vertical exaggeration depicts nine domed-shaped rises along the bluff. The subtle mound-like features not visible on the 1 m shaded relief image are about 10.8–19.8 m (35.4–65 ft) in diameter with maximum relief of 32–38 cm (12–15in). Metrics extracted from the point profile should be taken as general estimates as the absolute apex and outer terminus of the features could not be determined, nor is it guaranteed that the laser happened to intercept those locations for each mound.

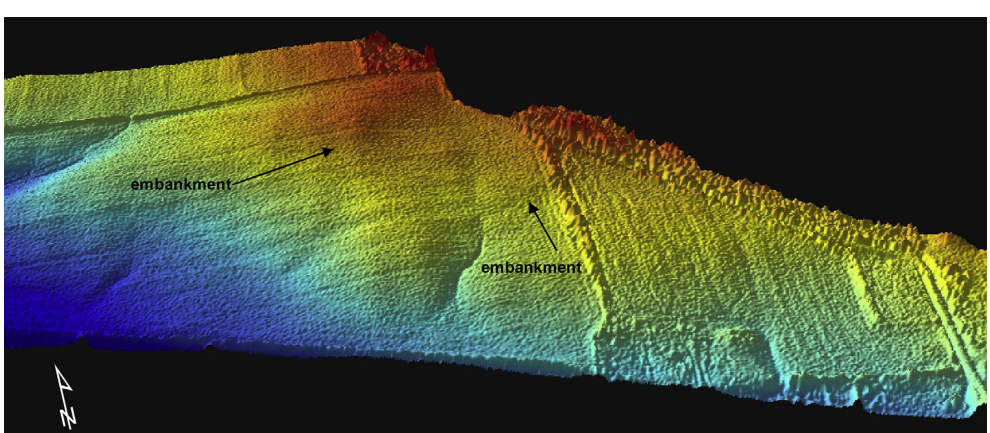

Fig. 7. A 75 cm BE DEM of the McKinney site created by spline interpolation; the Toolesboro mound area has been excluded from this BE DEM.

Table 1
UTM coordinates of interpreted features in NAD83 UTM 15N.

Description	*X*-coordinate	*Y*-coordinate
Orr Mound 1	662570.42	4556440.12
Orr Mound 2	662543.96	4556475.84
Orr Mound 3	662519.49	4556506.27
Orr Mound 4	662485.09	4556526.77
Green Mound 5	662465.89	4556545.26
Orr Mound 6	662384.55	4556625.33
Destroyed mound?	662344.55	4556670.25
Destroyed mound?	662311.50	4556704.61
Orr Mound 5	662426.04	4556568.46
Enclosure point 1	662186.08	4556770.37
Enclosure point 2	662146.32	4556592.95
Enclosure point 3	662300.29	4556631.70
Rise in center of enclosure	662206.48	4556650.05
NW anomaly		
Unreported feature? point 1	661900.42	4556980.97
Unreported feature? point 2	661897.77	4556941.29
Unreported feature? point 3	661947.38	4556968.41

The average ground point density in the enclosure area (open field) was 1 point per 1.6 m^2; however the distances between data points in some areas were as little as 0.75–0.9 m in the vicinity of the enclosure feature. A 75 cm resolution BE DEM was created from the ground points in the open field area using the spline interpolation method and then brought into ArcScene to determine if any additional features would be visible. No new information was provided by the new BE DEM, but the visualization of the enclosure boundaries was improved and the feature was clearly visible at 5× vertical exaggeration (Fig. 7).

A polygon feature class was digitized to outline the features detected in ArcScene and LP360. This includes an anomaly about 250 m northwest of the McKinney site in the general area of a suggested northern extension of the Toolesboro mound group (Table 1, NW anomaly; Alex and Green, 1995:21–22, 88) where mounds were reportedly explored (Pratt, 1876). This area does not have a recorded site designation, but should be surveyed in the future (Fig. 4). A point feature class shape file was created from the centroids of the Toolesboro mound features, three points each from the enclosure, and one each for the unrecorded features (Table 1). The point shape file as well as the polygon feature boundary file, IDW BE DEM, and spline BE DEM are on file at UI-OSA.

4. Discussion

This project was an unqualified success. A remnant embankment feature in the shape of a horseshoe 200 m by 160 m with 5–10 cm of surface relief––essentially flat to the unaided eye––was detected on a portion of the McKinney site in association with the Toolesboro mounds. Additionally, three more mound features were detected in the Toolesboro mound group. One is Green's (1993:12; Fig. 9) Mound 5. It may be a mound remnant as Green suggests or possibly a spoil pile. Regardless, the total surface anomalies in the Toolesboro mound group now stand at nine. Historic accounts report a minimum of 7–8 mounds and possibly 9 mounds present (Alex and Green, 1995; Green, 1993:4; Newhall, 1841:234). Pratt (1876:106) reported 12 mounds, but his description is not precise and probably includes the area we refer to as the Northwest anomaly. The LiDAR-detected enclosure feature closely matches one of the early descriptions of the enclosure as "a circular earthwork, resembling a horse shoe; the open part abutting the edge of the bluff among a group of mounds" (Stevenson, 1879:98). Two historic accounts claim the embankment enclosed 5–6 acres (2–2.5 ha) (Newhall, 1841:231–233; Shaw, 1878:258). Other later descriptions of the enclosure size vary such as Pratt's (1876:109). The LiDAR-detected feature identified in this study measures 2.6 ha in area when measured from the outer perimeter (Riley, 2012:4), enclosing an area of approximately 6.4 acres and corresponds in size to the original description by Newhall.

There is also strong agreement with Orr's (1934; Fig. 8) survey map of Toolesboro mound group 1–6 and his conclusion that mounds 4–6 were then nearly destroyed, although the point cloud profile demonstrated that those mounds have not been completely leveled (Figs. 6 and 8; Green, 1993:4–6). Three other mound-like features were also detected in line with Orr's mounds 1–6, one of

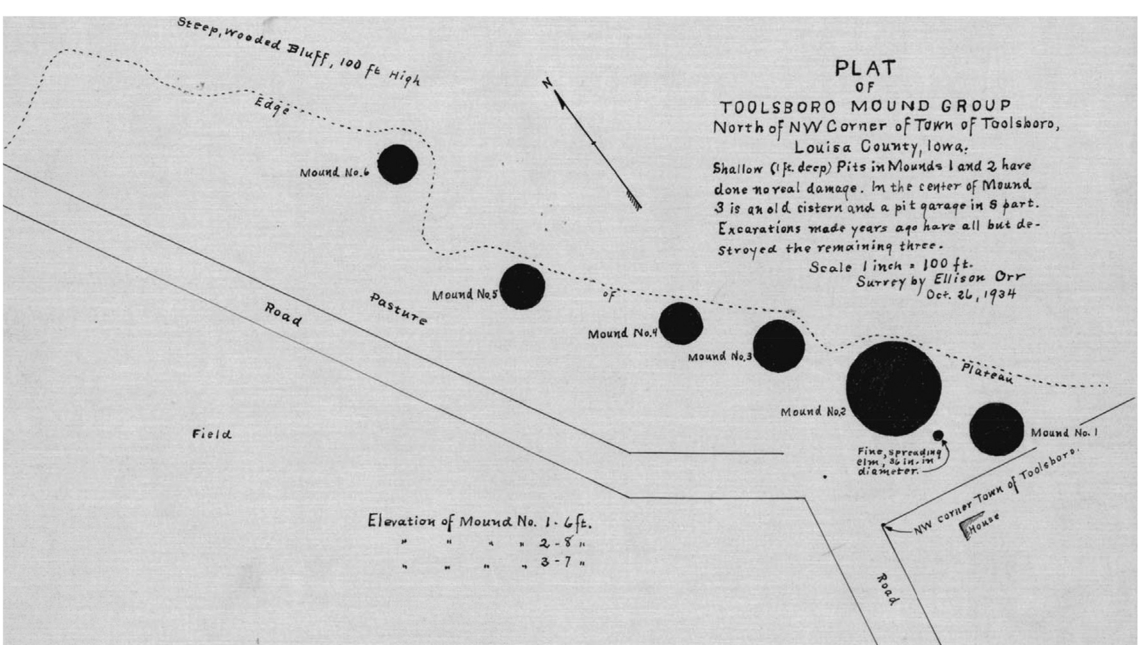

Fig. 8. Ink on linen map of Ellison Orr's (1934) survey of the Toolesboro mound group. Electronic copy of the original on file at the Office of the State Archaeologist of Iowa.

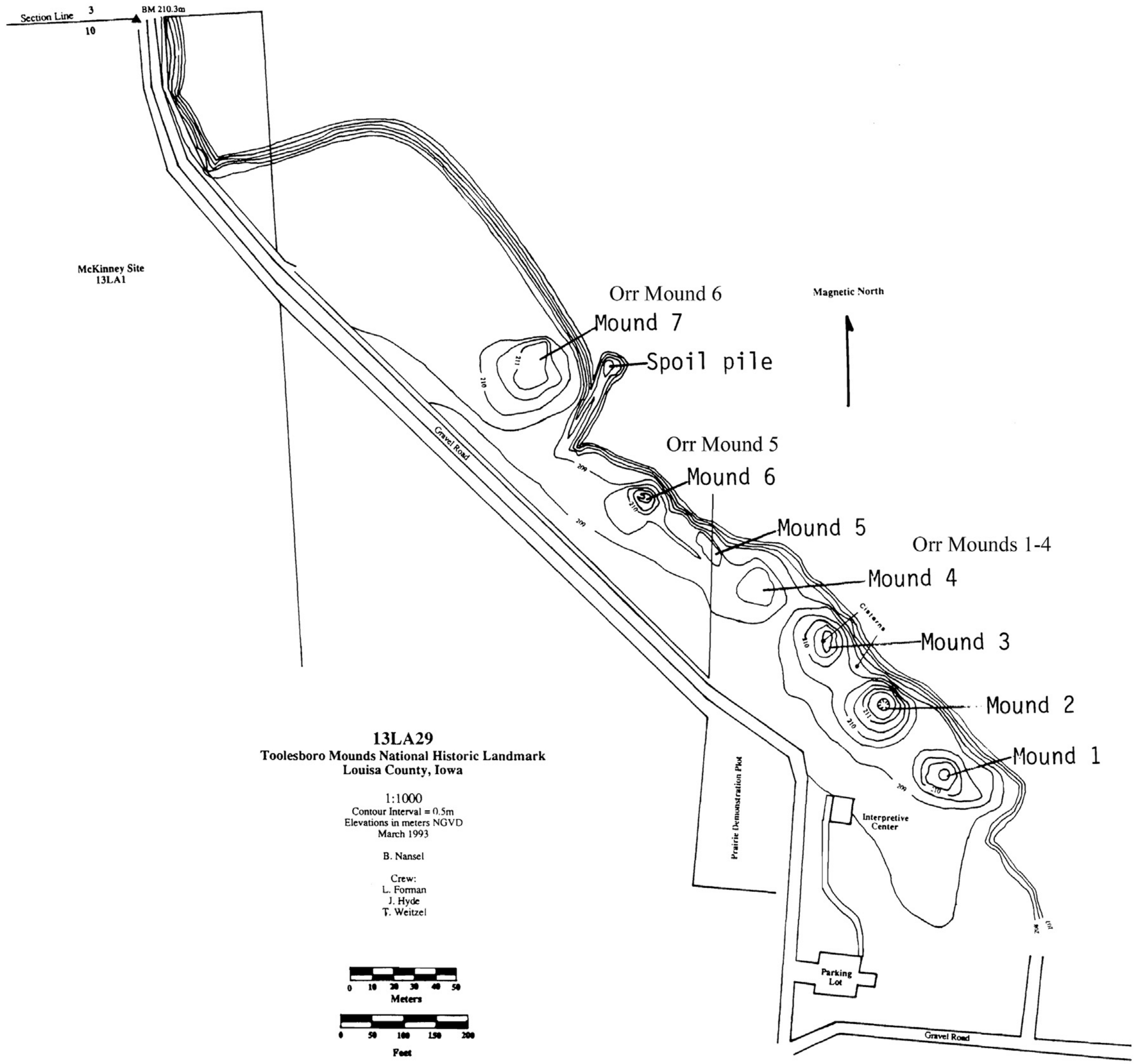

Fig. 9. Current map of the Toolesboro mound group. Modified from Green (1993):12.

which is Mound 5 mapped by Green (1993:12; Fig. 9); the other two are just beyond Orr's Mound 6 (Green's Mound 7). As mentioned historic accounts vary but a row of at least 7 to 8 mounds and possibly a ninth in association with the embankment feature as well as other mounds in the vicinity of the Toolesboro mound group to the immediate northwest (the northwest anomaly we report) bring the estimated total number of mounds to 12 (Alex and Green, 1995; Alden, 1844; Green, 1993:4; Newhall, 1841:234; Pratt, 1876; Tiffany, 1988). As Alex and Green (1995:22; Green, 1993:3) discuss there is difficulty in determining total mound numbers and mound excavation locations from the antiquarian excavations of the 19th century at Toolesboro where locational data are confusing or lacking. Orr's (1934) map is the first accurate survey of the Toolesboro mound group. Later work reported by Green (1993), which identified a seventh mound (Green's Mound 5), supports Orr's work.

5. Conclusions

LiDAR data was used with various geo-visualization and interpolation techniques to locate a historically reported earthwork enclosure at the McKinney site and eight mounds in the Toolesboro mound group. A possible ninth mound or an excavation spoil pile in the Toolesboro mound group was identified as well as a mound-like anomaly in the field north of the McKinney site that may account for the estimated total of 12 mounds originally at the site, and another circular anomaly within the enclosure feature. Historic accounts support our conclusions regarding the enclosure and the mounds. There are historic accounts of mounds but no modern survey in the area of the anomaly north of 13LA1. There is no clear historic record for the mound-like feature detected in the enclosure; Alden's (1844) description is muddled and the mounds referred to as "inside the fort" by him are the main Toolesboro mound group in our opinion.

The next step in the analysis will be to ground truth these results by first preparing a high-precision surface relief map of the enclosure area using a robotic total station. The resulting relief map may yield more precise topographic detail for the enclosure beyond that provided by our LiDAR study. Using GPS data and previous excavation benchmarks, the high-precision topographic map will also geo-reference previous major excavation units at the McKinney site (Tiffany, 1988; Hollinger, 2005) in relation to the enclosure and mounds. Second, additional subsurface data on the enclosure and immediate surrounds can be gathered using geophysical

techniques, such as a fluxgate magnetometer, which have been highly successful in detecting and mapping subsurface features at archaeological sites on the U.S. Great Plains and in Iowa (Kvamme, 1999, 2001, 2003a, 2003b, 2006, 2007, 2010). Geophysical mapping should define the enclosure banks as well as any subsurface features such as post molds, hearths, storage pits, or house basins which may relate to the Middle Woodland use of the enclosure area or the later Oneota reuse of the same area. This information is essential for future research on the Middle Woodland utilization of the general McKinney site area.

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